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RESULTS OF A WIND TUNNEL PRESSURE LOADS TEST OF THE 0.03-SCALE SPACE SHUTTLE ORBITER (MODEL 47-0) IN THE 8x7-FOOT LEG OF THE NASA/ARC UNITARY PLAN WIND TUNNEL (OA146)

Volume 2 of 2

SPACE SHUTTLE AERO THERMODYNAMIC DATA REPORT

(NASA-CR-167653) RESULTS OF A WIND TUNNEL PRESSURE LOADS TEST OF THE 0.03-SCALE SPACE SHUTTLE ORBITER (MODEL 47-0) IN THE 8 x 7 FOOT LEG OF THE NASA/ARC UNITARY PLAN WIND TUNNEL (OA146), VOLUME 2 (Chrysler Corp.)

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Volume 2 of 2

by

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Space Transportation & Systems Group

Prepared under NASA Contract Number NAS9-16283

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Houston, Texas

WIND TUNNEL TEST SPECIFICS:

Test Number:	ARC 87SWT 318-1
NASA Series Number:	OA146
Model Number:	47-0
Test Dates:	11-27-78 thru 12-7-78
Occupancy Hours:	116

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ABSTRACT

This document presents results from a wind tunnel test of a 0.03-scale model Space Shuttle Orbiter (Model 47-0). Tests were conducted in the Ames Research Center 8x7-foot leg of the Unitary Plan Wind Tunnel during the period November 27, 1978 to December 7, 1978. The shuttle program test designation was OA146 and the Facility Test Number was 318-1.

The test objectives met obtained both distributed pressures and force and moment data on the orbiter vehicle (OV102) in the hypersonic flow region for an aborted mission with orbiter return to launch site. Additionally, elevon hinge moments and wing loads were recorded.

All configurations were tested at a nominal Mach number of 3.5.

Data were recorded at discrete values of angle of attack ranging from 0° to 40°, at 0° and $\pm 4^{\circ}$ angle of sideslip. This test matrix required approximately 154 runs and 116 tunnel hours to complete. Results are reported in two volumes. Volume I contains sample pressure plots and tabulated force data. Volume II contains microfiche of the pressure data tabulation.

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NOMENCLATURE

SYMBOL	MNEMONIC	DESCRIPTION
A_C		Orbiter Sting Cavity Area, $ft.^2$
A_i		Area over which P_i acts, $ft.^2$
B_w		Wing balance bending moment, in-lbs.
b_{ref}	BREF	Orbiter Wing Span, in.
C_A	CA	Orbiter Axial Force Coefficient. Adjusted for sting cavity axial force coefficient.
C_{A_B}	CAB	Orbiter Base Axial Force Coefficient
C_{A_C}	CAC	Orbiter Sting Cavity Axial Force Coefficient. (Sting cavity pressure is adjusted to an average base pressure.)
C_{A_F}	CAF	Orbiter Forebody Axial Force Coefficient, $(C_A - C_{A_B})$
C_{A_U}		Orbiter Axial Force Coefficient uncorrected
C_{B_W}	CBW	Wing bending moment coefficient
C_e		Elevon mean aerodynamic chord, in.
$\bar{C}_w$		Wing mean aerodynamic chord, in.
Ch_{e_i}	CHEI	Inboard elevon hinge moment coefficient, about hinge line $X_o = 1387.0$
Ch_{e_o}	CHEO	Outboard elevon hinge moment coefficient, about hinge line $X_o = 1387.0$
C_ℓ	CBL	Orbiter Rolling Moment coefficient, body axis system
C_m	CLM	Orbiter pitching moment coefficient adjusted for sting cavity axial force effect
C_{m_B}		Orbiter base pitching moment coefficient
C_{m_U}		Orbiter pitching moment coefficient, uncorrected

NOMENCLATURE (Continued)

SYMBOL	MNEMONIC	DESCRIPTION
C_{m_F}	CLMF	Orbiter forebody pitching moment coefficient
C_{N_B}	CNB	Orbiter base normal force coefficient
C_{N_F}	CNF	Orbiter forebody normal force coefficient, $(C_N - C_{N_B})$
C_{N_U}	CN	Orbiter normal force coefficient, uncorrected
C_{N_W}	CNW	Wing normal force coefficient
C_n	CYN	Orbiter yawing moment coefficient
C_{pi}	CP	Surface tap i pressure coefficient
C_{TW}	CTW	Wing torsion coefficient
C_Y	CY	Orbiter side force coefficient
H_{e_i}		Inner elevon hinge moment, about X_o = 1387.0
H_{e_o}		Outer elevon hinge moment, about X_o = 1387.0
ℓ_b	LREF	Orbiter reference body length, [IML Nose to X_o] = 1290.3
M	MACH	Freestream Mach number
N_w		Wing balance normal force, lbs.
P_i		Pressure at Surface Tap i
P	P	Freestream static pressure
P_t	PT	Freestream total pressure
q	Q or Q(PSF)	Freestream dynamic pressure, lb/ft^2.
RN	RN/L	Reynolds number per unit length; /ft. model scale
S_e	SCALE	Elevon reference area ft.^{2}
S_w	SREF	Wing reference area, ft.^{2}

NOMENCLATURE (Continued)

SYMBOL	MNEMONIC	DESCRIPTION
T_t	TTF	Freestream total temperature, ^oF
T_W		Wing balance torsion, in-lbs
X_{MRP}	XMRP	(X), longitudinal; (Y) lateral; (Z) vertical moment reference point; inches
Y_{MRP}	YMRP	
Z_{MRP}	ZMRP	
X/ℓ_B	X/LB	Longitudinal distance (X) from orbiter nose to pressure orifice location divided by orbiter body length (ℓ_B)
X/C_{BF}	X/CBF	Longitudinal distance (X) from body flap hinge line to pressure orifice divided by body flap chord length
X_W/C_W	XW/CW	Longtiudinal distance (X_W) from wing leading edge to pressure orifice divided by wing local chord (C_W)
X_V/C_V	XV/CV	Longitudinal distance (XV) from leading edge of vertical tail to pressure orifice divided by tail local chord (C_V)
X/C_{SB}	X/CSB	Longitudinal distance (X) from speed brake line to pressure orifice divided by speed brake chord (C_{SB})
Y/b_{BF}	Y/BBF	Lateral distance (Y) from left hand side of body flap to pressure orifice divided by body flap span (b_{bf})
Y/b_W	Y/BW	lateral distance (Y) from orbiter centerline to pressure orifice divided by wing semi-span ($b_W/2$)
Y_o	YO	Lateral distance from orbiter centerline, positive to the right, inches
Z/b_{SB}	Z/BSB	Vertical distance (Z) from tail root chord to pressure orifice divided by speed brake span (b_{BS})
Z_V/b_V	ZV/BV	Vertical distance (Z_V) from tail root chord to pressure orifice divided by tail span (b_V)

NOMENCLATURE (Continued)

SYMBOL	MNEMONIC	DESCRIPTION
-	TAP NO	Pressure orifice number
α	ALPHA	Angle of attack, degrees
β	BETA	Angle of sideslip, degrees.
K_{δ_i}	-	Inboard elevon deflection constant, $^\circ$/in-lb.
K_{δ_o}	-	Outboard elevon deflection constant, $^\circ$/in-lb.
δ_{bf}	BDFLAP	Body flap deflection, degrees
δ_e	ELEVON	Elevon deflection, degrees
δ_{ei}	ELVI	Inboard elevon deflection, degrees
δ_{eo}	ELVO	Outboard elevon deflection, degrees
δ_r	RUDDER	Rudder deflection, degrees
δ_{sb}	SPDBRK	Speed brake deflection, degrees
ϕ	PHI	Radial position of pressure orifice on orbiter fuselage; $\phi = 0$ on bottom $\mathbb{C}_L$, positive clockwise from pilots view.

$NF = q\ S_w\ C_N$	Orbiter Normal Force
$AF = q\ S_w\ C_A$	Orbiter Axial Force
$PM = q\ S_w\ \bar{c}_w\ C_m$	Orbiter Pitching Moment
$YM = q\ S_w\ b_{REF}\ C_n$	Orbiter Yawing Moment
$SF = q\ S_w\ CY$	Orbiter Side Force
$RM = q\ S_w\ b_{REF}\ C_\ell$	Rolling Moment

<u>Wing Load Indicators</u>

m_1	Momemt at Wing Gauge 1
m_2	Moment at Wing Gauge 2
m_3	Moment at Wing Gauge 3

Hinge Moments

H_{ei}	Inboard elevon hinge moment
H_{eo}	Outboard elevon hinge moment

INTRODUCTION

This report presents the results of tests on the OV-102 Orbiter where airloads and venting characteristics during Return to Launch Site (RTLS) entry modes were obtained using a 0.03-scale model (47-0) in the NASA/ARC Unitary Plan Wind Tunnel.

Testing was conducted at a nominal Mach number of 3.5 to obtain data in a matrix of α/β conditions where the angle of attack varied from 0° to 40° at angles of sideslip of 0° and $\pm4^\circ$. Control surface settings included; rudder (-10°, 0°, $+10^\circ$), speedbrake (0°, 25°, 55°, 87.2°), body flap (-11.7°, 0°, 16.3°) and elevons (-15°, 0°, $+10^\circ$).

Force data recorded included 6-component vehicle data, 3-component wing data and both inboard and outboard elevon hinge moment data. Recorded pressure data included twenty base pressures, two balance sting cavity pressures and 617 model surface pressures.

Included in this report are details of the data reduction techniques used by the facility to obtain the final data, complete information on instrumentation locations, type and operations of all test instrumentation, specific model configurations tested, and descriptions of the test facility and test procedures.

Due to the volume of pressure data obtained, only sample pressure plots are presented. No force data plots were made. This report is in two volumes. Volume I presents the sample pressure plots and the force data tabulations. Volume II contains microfiche of the pressure data tabulation. An index of the Pressure Data by page number and microfiche page number is shown below:

Pressure Data 4th Character ID	Description	Print Normal Page No.	Microfiche Page No.
B	Orbiter Fuselage	1-578	1-10
E	Orbiter Base	579-805	10-13
F	Body Flap - bottom	806-934	13-15
G	Body Flap - top	935-1063	15-18
J	Miscellaneous	1064-1158	18-19
L	L.H. Wing - lower surface	1159-1963	19-32
P	R.H. Inside Speedbrake	1964-2092	32-34
U	L.H. Wing - upper surface	2093-2821	34-45
V	Vertical Tail (L.S.)	2822-2981	45-48

NOTE: Tabulated pressure data displayed in Volume 2 have been corrected for the bad orifice readings listed in Tables VIa through VIg.

CONFIGURATIONS INVESTIGATED

The test article provided was a 0.03-scale replica of the Rockwell International Space Shuttle Orbiter.

This Orbiter was in accord with the Rockwell International "-140 A/B" configuration as defined on model drawing SS-A00147, release 12, which is a fairing of the VL70-000140B wing, VL70-000200, to the VL70-000140A fuselage. Additionally, the later VL70-000140C Orbiter Maneuvering System (OMS) pods were substituted, these being a combination of the VL70-08410 and VL70-08401 drawings. For the purpose of this test and report, this combination is referred to as "-140 A/B/C/R."

The spacecraft was of blended wing body design with a double delta planform ($81^{\circ}/45^{\circ}{}_{LE}$) 12% thick wing and full-span elevons with a 6-inch interpanel gap between the independently deflectable inner and outer panels. A single centerline vertical tail with rudder and/or speedbrake capability was mounted between the two OMS pods, and a single body flap to aid in trim control during reentry from orbit was fitted on the lower trailing edge of the fuselage; the rudder/speedbrake and body flaps were also deflectable on this model. The uncovered RCS forward thruster ports at the fuselage nose were simulated. The SSME nozzles were partially simulated. The simulated Orbiter configuration is shown in Figure 2a.

Construction

The model was principally fabricated of Armco 17-4 and 7076-T6 Aluminum Alloy with some contouring with Renite, an epoxy filler resin. The model was designed and constructed to have a safety factor of five (5) based on ultimate strength, and three (3) based on yield strength on all components.

The Orbiter was fabricated around a central balance block of 17-4 Armco stock, bored and sleeved, to accept a 2.50-inch balance. Various aluminum parts were attached to the balance block to make up the Orbiter. The left-hand side of the Orbiter and Orbiter base were instrumented with 209 pressure taps.

The two OMS pods were fabricated of 7076-T6 aluminum alloy. The SSME and OMS nozzles were simulated in aluminum as were the RCS thrusters. The SSME nozzles were cut away to allow for sting clearance. The OMS pod was instrumented with 22 pressure taps.

The wing was a 2-piece aluminum article screwed to a central stainless steel wing beam. This beam, of cross-shaped planform, supported one wing on a tang on each side of the central plate. The right-hand tang was instrumented with strain gauges to form the 3-component wing load indicator balance. While the center of this beam formed the outer mold line of the bottom of the Orbiter, the wings were made integral with the glove, and a labyrinth seal was provided on the metric side to improve the data quality. The left-hand wing was instrumented with 285 pressure taps. Each of the wings was fitted with deflectable inboard and outboard elevons which were supported in torsion only by a beam mounted on the hingeline, and in all other degrees of freedom by plain bearing hinges; also, on the scale hingeline. Identical right-hand and left-hand elevon supports insured similar aeroelastic deflections. The opposite end of the elevon support beam was fitted with a ball bearing to minimize hysteresis effects. Construction details are shown in Reference 1. For negative elevon deflections (T.E. up), simulated flipper doors were fitted to the upper wing surface.

An aluminum body flap with 40 pressure taps was provided. Pairs of holes between the body flap bracket and the hinge shaft allowed for selection of deflection settings.

The vertical tail, constructed of 17-4 Armco, was a pressure-instrumented surface with 75 pressure taps (including one of the base group #301). The single-plane hinged rudder/speedbrake assembly consisted of panels, each individually pinned to the shaft. Sets of hole pairs between the panels and the shaft provided speedbrake settings. The entire shaft was then rotated and pinned to provide rudder deflections. Thirty (30) additional pressure taps were provided on the right side, inside face, of the speedbrake.

The following nomenclature was used to designate the Orbiter model components during this test:

Orbiter - B_{62} C_9 E_{64} F_9 M_{16} R_5 V_8 W_{131} N_{112} FD_3 N_{28}

Where:

Nomenclature	Components
B_{62}	Body (-140 A/B)
C_9	Canopy (-140 A/B)
E_{64}	Elevons (OV-102)
F_9	Body Flap
M_{16}	Short OMS pods (-140C)
R_5	Rudder (-146A)

CONFIGURATIONS INVESTIGATED (Concluded)

V_8	Vertical tail (-146A)
W_{131}	Wing (OV-102)
N_{112}	SSME Nozzles (OV-102)
FD_3	Flipper Doors
N_{28}	OMS Nozzles

INSTRUMENTATION

The model was installed with the wings vertical on a single 6-component internal strain gauge NASA/ARC 2.50-inch task MKXI balance, utilizing both the Rockwell W-1185-5 36° bent sting and the W-1185-3 15° bent sting.

Pressure instrumentation consisted of 639 static pressure orifices, individually plumbed to one of two scanivalve assemblies, each containing 8 S-type modules. The distribution of the pressure orifices over the model is as follows:

Oribter Base	20
Main Balance Cavity	2
Fuselage	165
OMS Pod	22
Body Flap	40
Left Hand Wing	285
Vertical Tail	75
Speed Brake Cavity	30
Total	639

The array of pressure taps is shown in Figures 2(d) thru 2(j). Tabulation of the pressure tap locations is presented in Tables III thru V.

During the first 46 runs, it was determined that the low- and mid-range scanivalves were bad. Those data have been given values of 0.0. Similarly, a post-test review of the data has shown other scattered pressure orifice readings to be bad and these likewise have been given 0.0 values. Table VI delineates the pressure data which have been deleted.

The right-hand wing was supported on a single-beam three-component balance which supported the panel in all degrees of freedom. Two bending moment and one torsion moment flexures were provided. The wing load indicators were calibrated by the Rockwell Los Angeles Division prior to test entry, with the results given to Ames data reduction prior to the test.

The right-hand elevons were instrumented to measure hinge moments directly via a beam that supported the panel in torsion about a hinge line coincident with the scale hinge line. The right-hand inboard and outboard elevons were calibrated by the Rockwell Los Angeles Division prior to test entry. Gauge sensitivities and deflection constants were furnished to Ames for each elevon deflection.

All instrumentation leads were routed internal to the stings. Access holes for instrumentation leads were provided in the W-1185-S sting near the orbiter base. All reference, backing, and calibrated pressure tubes were also routed internal to the sting.

The on-line data reduction for each run was obtained by using the ARC DEC computer in the 9x7-ft. tunnel and the Beckman system in the 8x7-ft. tunnel. The off-line calculations were provided by the ARC IBM 360 computer.

TEST FACILITY DESCRIPTION

The Ames 8x7-foot Supersonic Wind Tunnel is a closed-return, variable-density test section. The nozzle has flexible side walls with fixed upper and lower surfaces. Mach number range is continuously variable from 2.45 to 3.5. Tunnel stagnation pressure can be varied from 0.3 to 2.0 atmospheres and Reynolds number per foot varies from 1.0×10^6 to 5.0×10^6.

TEST PROCEDURE

Before the test began, calibration and checkout of all model instrumentation systems were performed at the Rockwell Los Angeles Division. The model and all test equipment were then shipped to the NASA/Ames Research Center where model/system reliability was demonstrated.

After receipt of the model and test hardware at ARC, additional check-out procedures and model preparation took place. The following pieces of hardware were installed in the test section:

1) ARC/Ames 2.5-inch MKXI Balance
2) Rockwell 36° Bent Sting #W-1185-5
3) Rockwell 15° Bent Sting #W-1185-3
4) G/D 12-EK-090 Sting Pitch Mechanism
5) 12-ZK-090-3 Drag Link
6) 12-ZK-090-15 Sting Knuckle

A sketch of model 47-0 installed on the above hardware in the ARC 8x7-foot tunnel is shown in Figure 2b. Prior to model installation on the balance, a calibration of the Rockwell-W1185 sting, was performed to determine the ratio of knuckle angle to model angle. Check loading of the force balance was accomplished by ARC personnel to determine deflection constants. This weight/deflection calibration was performed in the tunnel using the test hardware and the data reduction system.

DATA REDUCTION

Data measured and recorded during test OA146 consisted of the following:

1) Tunnel freestream parameters
2) Force balance data (for sting deflections)
3) Model angle of attack and sideslip corrected for balance and support-hardware deflections
4) Orbiter static pressures
5) Three-component wing balance data, reduced using first-order interaction constants
6) Elevon hinge moments
7) Elevon deflections adjusted for aeroelastic loads

Standard arc methods for computing tunnel parameters, balance forces and moments, orbiter pressures, and model attitudes were used. Six-component force and moment data were recorded and reduced for the orbiter. Attitude and position locations of the model were corrected for sting/balance deflections.

The following reference dimensions were used:

Symbol	Description	Value: Model Scale	Full Scale
b_{REF}	Wing Referenced Span, In.	28.1004 In.	936.68 In.
c_e	Elevon Mean Aerodynamic Chord, In.	2.721 In.	90.7 In.
$\bar{c}_w$	Wing Mean Aerodynamic Chord, In.	14.244 In.	474.8 In.
ℓ_b	Orbiter Reference Length, In.	38.709 In.	1290.31 In.

DATA REDUCTION (Continued)

Symbol	Description		Value: Model Scale	Value: Full Scale
MRC	Orbiter Moment Reference Center			
		Xo	32.301 In.	1076.68 In.
		Yo	Ø	Ø
		Zo	11.25 In.	375.00 In.
MRC Bal.	Balance Reference Center			
		Xo	32.469 In.	
		Yo	Ø	
		Zo	11.70 In.	
S_e	Elevon Reference Area, Ft^2		.1890 Ft^2	210 Ft^2
S_w	Orbiter Reference Area, Ft^2		2.4210 Ft^2	2690.0 Ft^2

DATA REDUCTION (Continued)

Reference Dimensions and Constants

Symbol	Location	Value (FT^2, model scale)
A_C	Orbiter Sting Cavity	.05476
A301	Orbiter Base	0
A302		0
A303		0.096560
A304		0
A305		0
A306		0.005300
A307		0.007960
A308		0.010613
A309		0.013230
A310		0
A311		0.023217
A312		0.016584
A313		0.001327
A314		0.011940
A315		0.013798
A316		0.007297
A317		0.012603
A318		0.017247
A319		0.021758
A320		0.015920
A321		0.017247
A322		0.014328
A323		0.006103
A324		0.026003
A401 thru A404	Orbiter Body Flap	0
A405		0.011551
A406		0.010267
A407		0.009838
A408		0.0077004
A409 thru A412		0
A413 thru A416		0.012834/orifice
A417 thru A436		0
A437		0.011551
A438		0.010267
A439		0.009838
A440		0.0077004

Standard NASA/Ames data reduction equations were used to reduce balance-recorded forces and moments, and measured pressures.

All force data were reduced about the Orbiter moment reference center. Axial force was adjusted for the difference between the average sting cavity pressure and an average base pressure. Forebody axial force coefficient was computed by adjusting the base pressure to freestream.

$$C_A = C_{A_U} - C_{A_C}; \quad C_{A_F} = C_A - C_{A_B}$$

where

$$C_{A_C} = -(C_{P_{C_{AVG}}} - C_{P_{B_{AVG}}}) \, (A_C/S_W)$$

and

$$C_{P_{C_{AVG}}} = (C_{P_{304}} + C_{P_{310}})/2$$

$$C_{P_{B_{AVG}}} = (C_{P_{306}} + C_{P_{307}} + C_{P_{308}} + C_{P_{309}} + C_{P_{312}} + C_{P_{313}})/6$$

$$C_{A_B} = (-1/S_W) \left\{ \sum_{i=301}^{324} (C_{P_i})(A_i) + (C_{P_{B_{AVG}}}) \, (A_C) \right\}$$

Normal force and pitching moment coefficients were adjusted for the base area times the pressure terms as follows:

$$C_{N_B} = (-1/S_w)(\tan 14.75^o) \sum_{i=301}^{318} (C_{P_i})(A_i) + (-1/S_w) \sum_{i=401}^{440} (C_{P_i})(A_i)$$

$$C_{M_B} = (-1/S_w C_w) \left\{ -X_1(\tan 14.75^o) \sum_{i=301}^{318} (C_{P_i})(A_i) - X_2 \sum_{i=401}^{440} (C_{P_i})(A_i) + Z_1 \sum_{i=301}^{324} (C_{P_i})(A_i) \right\}$$

where X_1, X_2, and Z_1 are distances to the centroid of the areas from the moment reference center. $X_1 = 12.640$; $X_2 = 14.640$ and $Z_1 = 0.450$ inches, model scale

$$C_{N_F} = C_{N_U} - C_{N_B}$$

$$C_{M_F} = C_{M_U} - C_{M_B}$$

The three-component wing balance data were reduced taking into account the supplied first-order interaction constants. With m_1, m_2. and m_3, the output of the three flexures, as iterated, and using the constants a_m, d, and e_m as shown in figure 2(c),

N_w = Wing Normal Force

$$= \frac{m_1 - m_2}{a_m} \text{ lbs.}$$

B_w = Wing bending moment about $Y_o = 105$

$$= m_2 + \frac{(m_1 - m_2)}{a_m} d \text{ in-lbs.}$$

$$T_w = m_3 + \frac{(m_1 - m_2)}{a_m} e_m \text{ in-lbs.}$$

T_w = Wing torsion about $X_o = 1307$

Following,

$$C_{N_w} = \frac{N_w}{qS_w}$$

$$C_{B_w} = \frac{B_w}{qS_w\, b_{ref}}$$

$$C_{T_w} = \frac{T_w}{qS_w\, \bar{c}_w}$$

The elevon hinge moment gauge output is linear with applied moment, Then if,

H_{ei} = inboard elevon hinge moment

H_{eo} = outboard elevon hinge moment

$$Ch_{e_i} = \frac{H_{e_i}}{q\, S_e c_e}$$

$$Ch_{e_o} = \frac{H_{e_o}}{q\, S_e c_e}$$

The presented elevon deflection was adjusted for aeroelastic load

$$\delta_{ei} = \delta_{ei} \text{ / no load} + H_{ei} \; K_{\delta_i}$$

$$\delta_{eo} = \delta_{eo} \text{ / no load} + H_{eo} \; K_{\delta_o}$$

where K_{δ_i}, K_{δ_o} are linear deflection constants.

Pressure coefficients for all model pressure measurements were computed using the equation:

$$C_{P_i} = (P_i - P_o)/q$$

where:

P_i = Pressure at surface tap i

P_o = Freestream static pressure

q = Freestream dynamic pressure, LB/FT^2.

REFERENCE

1. SD78-SH-0130, "Pretest Information for Test OA146 of the 0.03-Scale Pressure Loads Space Shuttle Orbiter Model 47-Ø in the 8x7-Ft. Leg of the NASA/ARC Unitary Plan Wind Tunnel," dated Aug. 24, 1978.

TABLE I

TEST : OA 146		DATE : 12/7/78	
TEST CONDITIONS			
MACH NUMBER	REYNOLDS NUMBER (per unit length)	DYNAMIC PRESSURE (pounds/sq. inch)	STAGNATION TEMPERATURE (degrees Fahrenheit)
3.5	2.5×10^6	375	120°

BALANCE UTILIZED: TASK 2.5" MK XI

	CAPACITY:	ACCURACY:	COEFFICIENT TOLERANCE:
NF	1700/1700 lbs		
SF	700/700 lbs		
AF	1000 lbs		
PM			
RM	2000 in-lbs		
YM			

COMMENTS:

TABLE II

TEST : ØA 146 (ARC 318-1-97)

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE : 12/7/78

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	δ_e	δ_{IT}	δ_R	δ_{SB}	NO. OF RUNS		α = 0	5	10	15	22.5	30	35	40	
R3G_01	ØV-102	–	A	0	0	0	0			13*	14*	15*	16*	17*	18*	19*	20*	
02		–	A			0	87.2			21*	*22(1)	23*	24*	25*	26*	27*	28*	
03		–	A			0											29*	
04		–	A			10				31*	32*	33*	34*	35*	36*	37*	38*	
05		–	A			-10				39*	40*	41*	42*	43*	44*	45*	46*	
06		–	B			10				47	48	49	50	51	52	53	54	
07		–	A			10				55	56	57	58	59	60	61	62(2)	
08		–	A			0				63	64	65	66	67	68	69	70	
09		–	A	10	-11.7	10				71	72	73	74	75	76	77	78	
10		–	A		-11.7	-10				79	80	81	82	83	84	85	86	
11		–	A		16.3	10	25			87	88	89	90	91	92	93	94	
12		–	A			0				95	96	97	98	99(3)				
13		–	A			-10				103	104	105	106	107	108	109	110	
14		–	A	-15		-10	55			111	112	113	114	115	116(4)	117	118	
15		–	A			0				119	120	121	122	123	124	125	126	
16		–	A			10				128	129	130	131	132	133	134	135	
17		–	A		-11.7	10	0			136	137	138	139	140	141	142	143	
18		–	A		-11.7	-10	0			144	145	146	147	148	149	150	151	
19		–	A		-11.7	-10	87.2			152	153	154	155	156	157	158	159	
20		–	A		-11.7	10	87.2			160	161	162	163	164	165	166	167	
21		–	A		11.7	0	55					127						

α OR β SCHEDULES: A) β = -4°, 0°, 4° B) β = -3°, 1.5°

TEST RUN NUMBERS

JEV

* LOW AND MIDRANGE SCANIVALVE DATA NO GOOD

(1) β = -4°, 0° (3) β = 0°, 4°

(2) 0°, 4° (4) β = -4°, 4°

NASA AF

TABLE III ORBITER FUSELAGE PRESSURE INSTRUMENTATION

ORB STA		ϕ RADIAL LOCATION ~ DEG																					
FULL	X_o/L_o	0	20	40	55	67.5	70	82	90	105	110	120	135	140	150	151	156	162	165	169	174	180	Σ
235	0	1																					1
245	.0075	2							3														2
265	.0233	5	6	7	8		9		10			11			12							13	9
295	.0465	17	18	19	20		21		22			23			24							25	9
325	.0698	29	30	31	32		33		34			35			36							37	9
380	.1124	41	42	43	44		45		46			47			48							49	9
385	.1163								53														1
399	.1271								54														1
440	.1589																				55		1
450	.1666	56	57	58	59		60		61			62					63			64		65	10
465	.1783															69		70					2
500	.2054	71	72	73	74		75		76			77		78	79				80			81	11
540	.2364	85		86	87				88			89			90				91			92	8
560	.2558	94		95			96		97			98			99				100			101	8
590	.2751	103		104			105		106			107			108				109			110	8
625	.3023	112		113			114		115			116			117				118			119	8
690	.3526	121		122			123		124			125			126				127			128	8
764	.4100							130															1
780	.4224	131		132			133		134			135			136				137			138	8
905	.5193							140															1
925	.5[illegible]	141		142			143		144			145			146				147			148	8
955	.5441					150																	1
974	.5602																						0
1070	.6318	152		153			154		155			156			157				158			159	8
1129	.6929							161															1
1215	.7795	162		163			164		165	166		167	168		169				170			171	10
1300	.8254	173		174			175		176	177		178	179		180								8
1318	.8393																						
1350	.8641																						
1375	.8835	183		184			185		186	187		188	189		190				191			192A	10
1390	.8951						193																1
1430	.4261	194		195			196		197	198		199	200		201				202			203A	10
1455	.9455																		202A			203A	2
1480	.9649	204		205			206		207	208		209	210		211				212				9
1520	1.0096										216 214	217 215											4
																						TOTAL	187

TABLE IV

ORBITER WING PRESSURE INSTRUMENTATION

	η	Y_o	X_w/C_w											X_o	X_e/C_e							Σ
			0	.01	.02	.05	.09	.15	.25	.40	.55	.70	.80	1360	-.10	.10	.20	.40	.60	.80	1.0	
TOP	.235	110	601	602	603	604	605	606	607	608	609	610	611									11
BOT			601	612	613	614	615	616	617			620	621									8
TOP	.299	140	622	623	624	625	626	627	628	629	630	631			633	634	635	636	637	638	639	17
BOT			622	640	641	642	643	644	645	646	647	648			650	651	652	653	654	655		15
TOP	.342	160	656	657	658	659	660	661	662	663	664	665			667	668	669	670	671	672	673	17
BOT			656	674	675	676	677	678	679	680	681	682			684	685	686	687	688	689		15
TOP	.427	200	690	691	692	693	694	695	696	697	698				700	701	702	703	704	705	706	16
BOT			690	707	708	709	710	711	712	713	714				716	717	718	719	720	721		14
TOP	.534	250	722	723	724	725	726	727	728	729	730				732	733	734	735	736	737	738	16
BOT			722	739	740	741	742	743	744	745	746				748	749	750	751	752	753		14
TOP	.619	290	754	755	756	757	758	759	760	761	762				764	765	766	767	768	769	770	16
BOT			754	771	772	773	774	775	776	777	778				780	781	782	783	784	785		14
TOP	.726	340	786	787	788	789	790	791	792	793	794				796	797	798	799	800	801	802	16
BOT			786	803	804	805	806	807	808	809	810				812		814	815	816	817		13
TOP	.811	380	818	819	820	821	822	823	824	825					827	828	829	830	831	832	833	15
BOT			818	834	835	836	837	838	839	840							844	845	846	847		11
TOP	.897	420	848	849	850	851	852	853	854	855					857	858	859	860	861	862	863	15
BOT			848	864	865	866	867	868	869	870					872		874	875	876	877		12
TOP	.961	450	878	879	880	881	882	883	884						886	887	888	889	890	891	892	14
BOT			878	893	894	895	896	897	898						900		902	903	904	905		11
	1.00	TIP						906	907						909			910		911	912	6
																				TOTAL		286

TABLE V

ORBITER SPEEDBRAKE, VERTICAL TAIL, BODY FLAP, AND ORBITER BASE PRESSURE INSTRUMENTATION

SPEED BRAKE

SPEED BRAKE Z_o FULL SCALE	T.P. INSIDE Z_o MODEL SCALE	η/SB	X/SBv .10	.25	.40	.65	.90	NO TAPS	ΣNo TAPS
600	18.0	.110	1801	1802	1803	1804	1805	5	5
630	18.9	.254	1806	1807	1808	1809	1810	5	10
666	19.8	.407	1811	1812	1813	1814	1815	5	15
690	20.7	.561	1816	1817	1818	1819	1820	5	20
720	21.6	.706	1821	1822	1823	1824	1825	5	25
750	22.5	.856	1826	1827	1828	1829	1830	5	30
								TOTAL	30

VERTICAL TAIL

Z_o	η	X_v/C_v 0	.03	.06	.16	.30	.52	.68	.88	.98	Σ
530	0.095	501	502	503	504	505	506	507	—	—	7
570	0.222	509	510	511	512	513	514	515	516	517	9
600	0.317	518	519	520	521	522	523	524	525	526	9
640	0.443	527	528	529	530	531	532	533	534	535	9
680	0.570	536	537	538	539	540	541	542	543	544	9
720	0.697	545	546	547	548	549	550	551	552	553	9
755	0.808	554	555	556	557	558	559	560	561	562	9
790	0.919	563	564	565	566	567	568	569	570	571	9
TIP	1.0	—	—	—	572	573	574	575	576	—	5
										TOTAL	75

BODY FLAP

η	X/CBF (BOT) -.10	.20	.60	.95	X/CBF (TOP) -.10	.20	.60	.95
.10	401	402	403	404	405	406	407	408
.20	—	—	—	—	—	—	—	—
.35	—	—	—	—	—	—	—	—
.50	409	410	411	412	413	414	415	416
.65	417	418	419	420	421	422	423	424
.80	425	426	427	428	429	430	431	432
.90	433	434	435	436	437	438	439	440
							TOTAL	40

ORBITER BASE

TAP #	Z_o	Y_o	TAP #	Z_o	Y_o
301	532	0	314	302	-78
303	470	0	315	414	-103
*304	405	55	316	376	-103
306	340	0	317	340	-103
307	302	0	318	302	-103
308	478	-38	319	514	-55
309	439	-38	320	492	-88
*310	405	-55	321	522	-96
311	302	-78	322	470	-96
312	439	-78	323	439	-107
313	410	-78	324	465	-130
				TOTAL	22

* CAVITY TAPS

TABLE VI.a.

PRESSURE DATA DELETED FROM ORBITER FUSELAGE

ELEMENT	DSID	BETA	ALPHA	PHI,ϕ	X/LB
FUSELAGE	Y3GB01,02, 03,04,05	ALL	ALL	70°	.2054
					.2558
					.2751
					.3023
					.3526
					.4224
				82°	.410
				90°	.4224
					.3526
					.3023
					.2751
					.2558
					.2364
					.2054
	Y3GB08	4	15	20	.1120
				40	.8254
				70	.8951
				150	.2364
	Y3GB13	4	10	0	.2558,.2751
				40	.2364,.2558
				40	.2751,.3023
				40	.6518
				55	.2364
				120,165	.3023,.8641
				135,150	.8641
				150	.3023,.8393
				180	.2751,.3023

TABLE VI.b.

PRESSURE DATA DELETED FROM L.H. WING UPPER SURFACE

ELEMENT	DSID	BETA	ALPHA	$\eta = 2Y/b_w$	X/C_w
LH WING UPPER SURFACE	R3GU06,07, 08,09,10,11 12,13	ALL	ALL	.342	.843
				.534	.738
				.726	.55,.896
				.961	.765
			21,28,32,38	.427	.25
	R3GU14,15	ALL	ALL	.342	.843
			ALL	.534	.738
			10,15,23	.726	.55,.896
			30,35,40	.726	.55,.896
			23,30,35,40	.427	.25
	R3GU16,17,18 19,20	ALL	10,15,23,30 35,40	.342	.843
				.534	.738
			30,35,40	.726	.55,.896
	R3GU21	ALL	10	.342	.843
		ALL	10	.534	.738
		8	10	.726	.55,.896
	R3GU08	4	15	.427	.802
	R3GU08	4	15	.299	.971

TABLE VI.c.

PRESSURE DATA DELETED FROM L.H. WING LOWER SURFACE

ELEMENT	DSID	BETA	ALPHA	$\eta = 2Y/b_w$	X/C_w
L.H. WING LOWER SURFACE	R3GL01	-4,0,4	35	.342	.809
		-4,0	35	.534	.738
		4	35	.619	.725
		-4,0	40	.342	.809
		-4,0	40	.619	.725
		-4	40	.726	.704
		4	35	.427	.802
		-4,0,4	40	.427	.802
		0	40	.299	.836
		0,4	40	.726	.704
		4	40	.342	.843
		0,4	40	.897	.642
	R3GL08	4	15	.226	.780
	R3GL13	4	10	.226	0,.03,.06,.54
	R3GL13	4	10	0	0,.02
	R3GL14	4	40	.299	.836
		-4	30	.299	.836
		-4,0,4	35	.299	.836
		-4	30	.342	.809
				.534	.738
				.619	.725
				.726	.704
		4	35	.726	.704
		4	35	.619	.725
	R3GL15	-4	35	.534	.738
		0		.299	.836
		0		.342	.809
		0		.427	.758
		-4,0	40	.726	.786
		-4,0	40	.961	.558
		4	40	.897	.641
	R3GL16	-4,0,4	10,15,23	.726	.704
			30,35,40	.726	.704
				.534	.738
				.427	.758

TABLE VI.c.(Concluded)

PRESSURE DATA DELETED FROM L.H. WING LOWER SURFACE

ELEMENT	DSID	BETA	ALPHA	$\eta = 2Y/b_W$	X/C_W
L.H. WING LOWER SURFACE	R3GL17	-4,0,4	23,30,35,40	.427	.802
	R3GL21	0,8	10	.726	.25
	R3GL21	8	10	.961	.558

TABLE VI.d.

PRESSURE DATA DELETED FROM VERTICAL TAIL

ELEMENT	DSID	BETA	ALPHA	Z/b_v	X/C_v
VERTICAL TAIL	R3GV18	ALL	40	.697	.520
	R3GV19	ALL	ALL	.919	.520
	R3GV20	4	15,23,35	.570	.680
		-4	23,30		
		0,4	30,40		
		4	30,40	.697	.680

TABLE VI.e.

PRESSURE DATA DELETED FROM SPEEDBRAKE

ELEMENT	DSID	BETA	ALPHA	Z/b	X/C
SPEEDBRAKE	R3GP08	4	15	.407	.9
	R3GP16	-4	40	.110	.9
	R3GP17	ALL	0,5,10,15	.110	.9
	R3GP18	-4	15,23	.110	.65
		ALL	0,5,10,15	.110	.90
		4	35	.110	.90
	R3GP19	ALL	35,40	.110	.90
	ALL	ALL	ALL	.856	.10
				.567	.40
				.254	.90

TABLE VI.f.

PRESSURE DATA DELETED FROM TOP SURFACE OF BODY FLAP

ELEMENT	DSID	BETA	ALPHA	$(Y/b)_{bf}$	$(X/C)_{bf}$
BODY FLAP TOP SURFACE	R3GG06 through R3GG21	ALL	ALL	.80	.20
	R3GG06	ALL	ALL	.10	-.10
		5	8	.10	.95
		5	13	.50	.60
		5	20	.50	.95
	R3GG07	4	15	.50,.65	.60
	R3GG08	4	15	.90	.20
	R3GG09	4	15	.10	.95
	R3GG09	4	23	.50	.60
	R3GG10	4	15	.10	.95
	R3GG13	4	10	.1,.5,.65,.8	.95
	R3GG14	-4	0	.80	.60
	R3GG15	-4	0	.80	.60
	R3GG15	4	35	.10	.20
	R3GG16	-4	0,15	.80	.60
	R3GG17	-4	0	.80	.60,.95
	R3GG18,19,20	-4	0	.80	.60,.95
		4	0	.80	.95
		-4	15	.80	.60

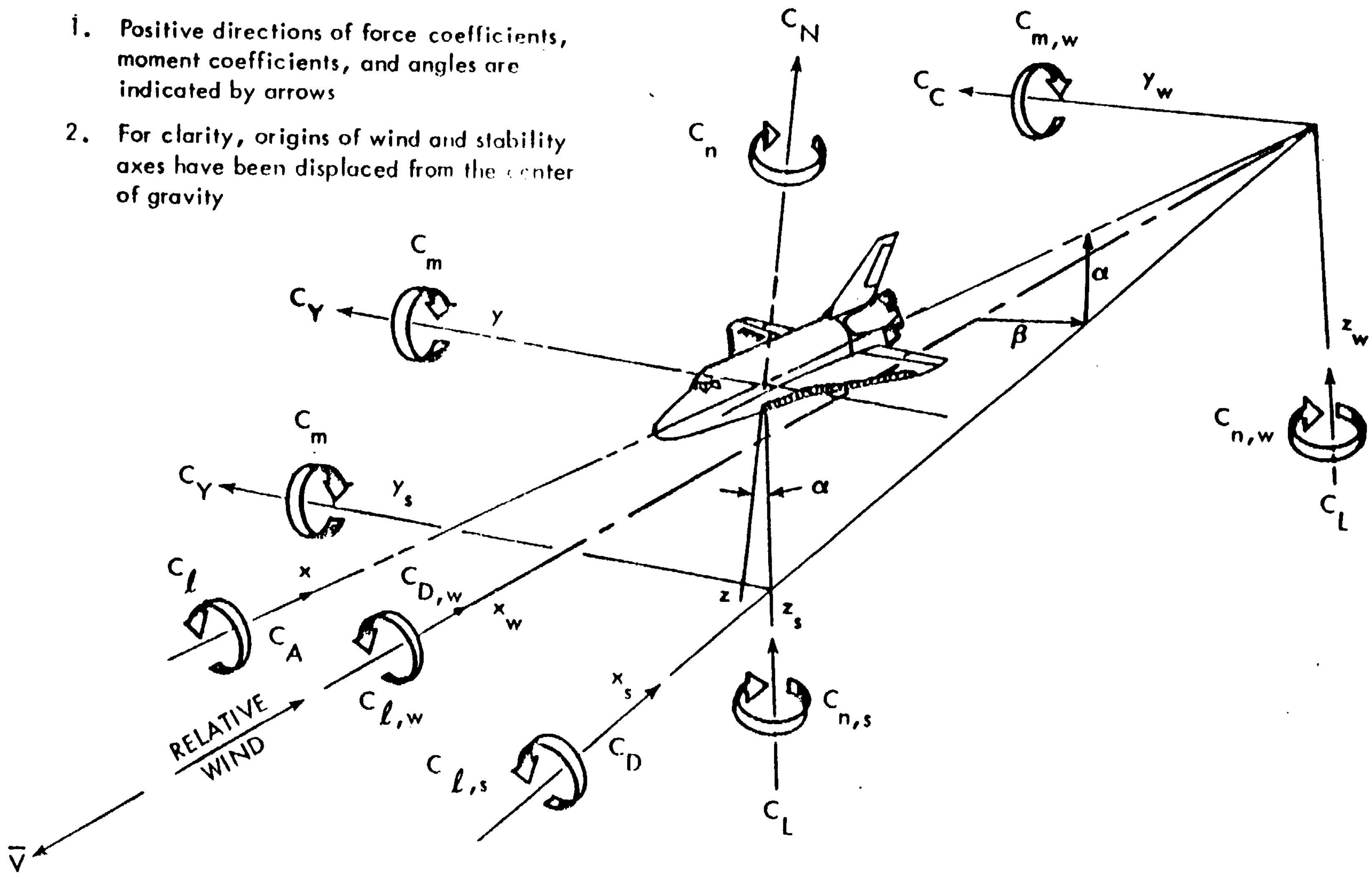
TABLE VI.g.

PRESSURE DATA DELETED FROM MISCELLANEOUS LOCATIONS

ELEMENT	DSID	BETA	ALPHA	TAP #	
Miscellaneous	R3GJ13	4	10	912	

Notes:

1. Positive directions of force coefficients, moment coefficients, and angles are indicated by arrows
2. For clarity, origins of wind and stability axes have been displaced from the center of gravity



a. Axis Systems

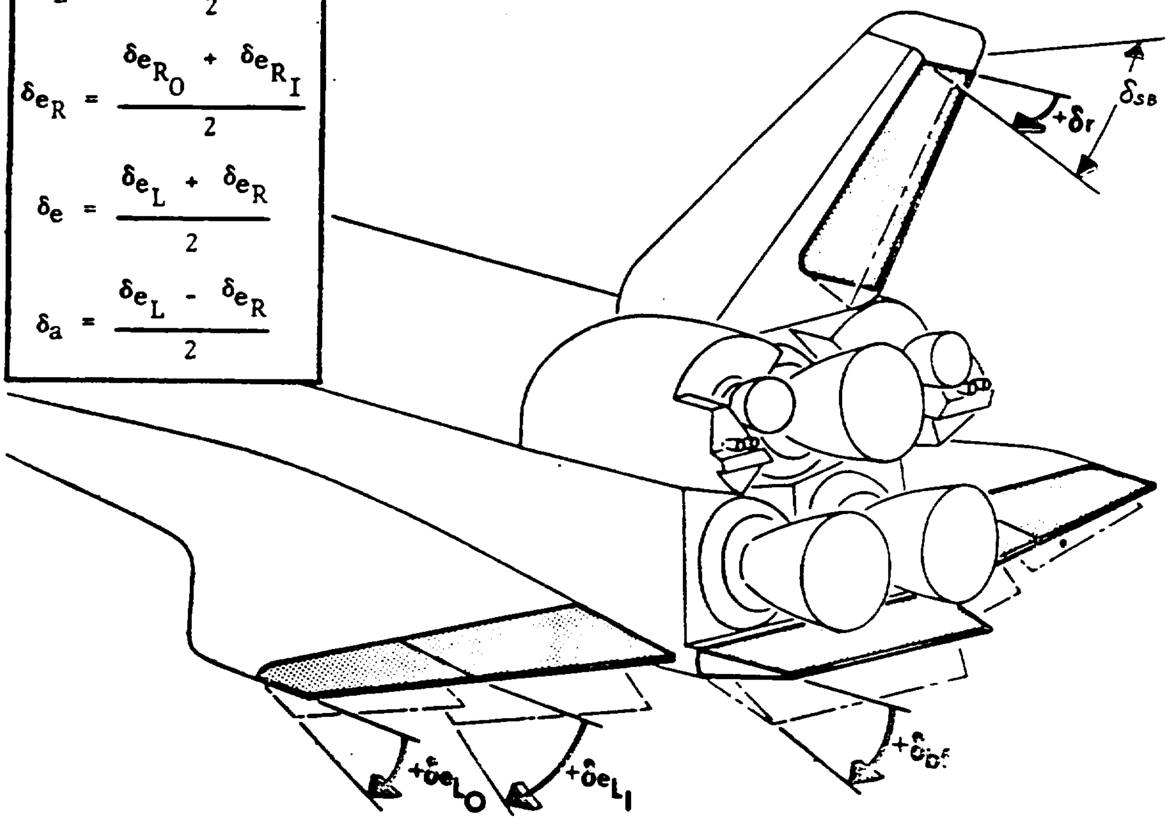
Figure 1. Model axis systems and sign conventions.

$$\delta e_L = \frac{\delta e_{L_O} + \delta e_{L_I}}{2}$$

$$\delta e_R = \frac{\delta e_{R_O} + \delta e_{R_I}}{2}$$

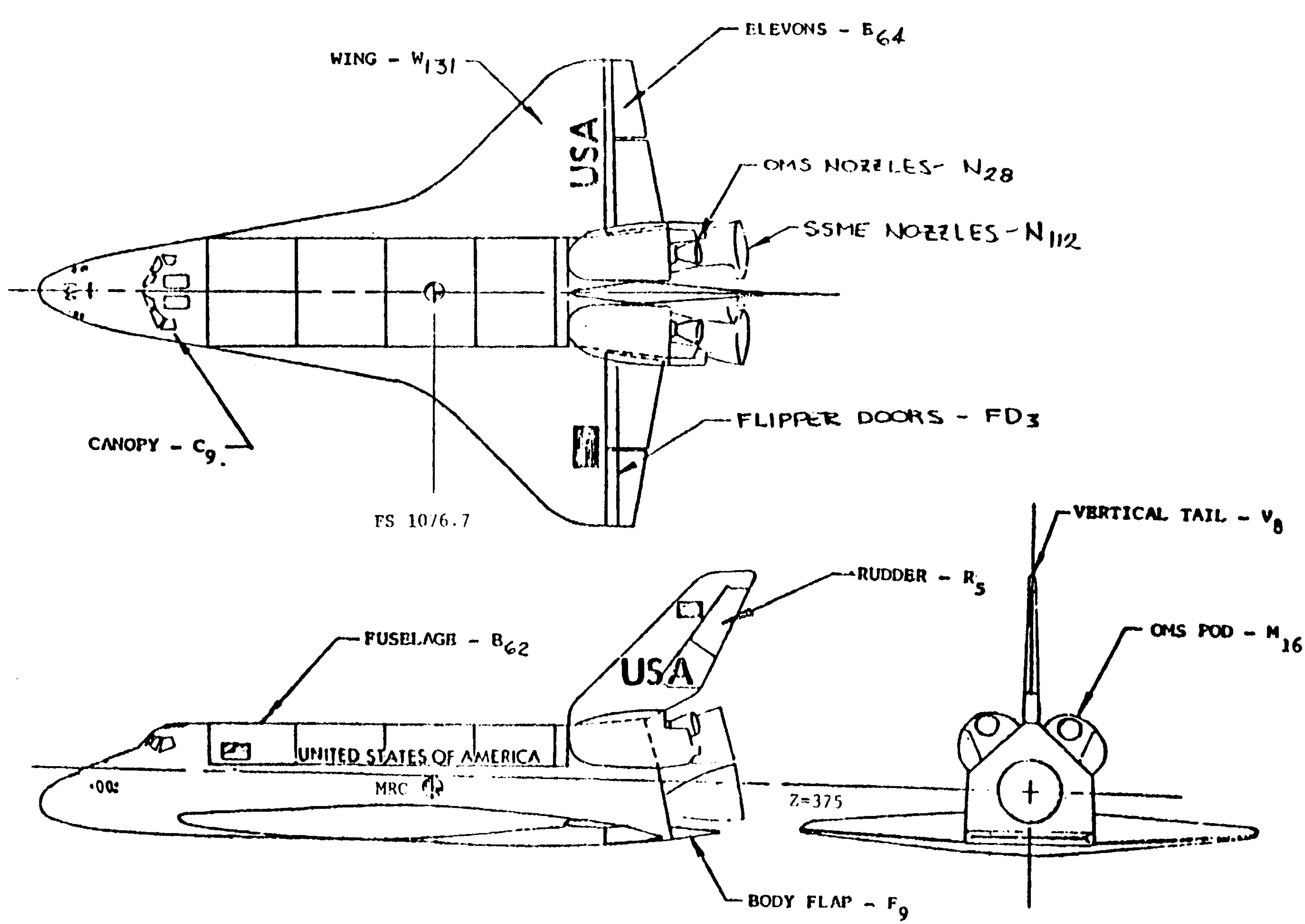
$$\delta e = \frac{\delta e_L + \delta e_R}{2}$$

$$\delta a = \frac{\delta e_L - \delta e_R}{2}$$

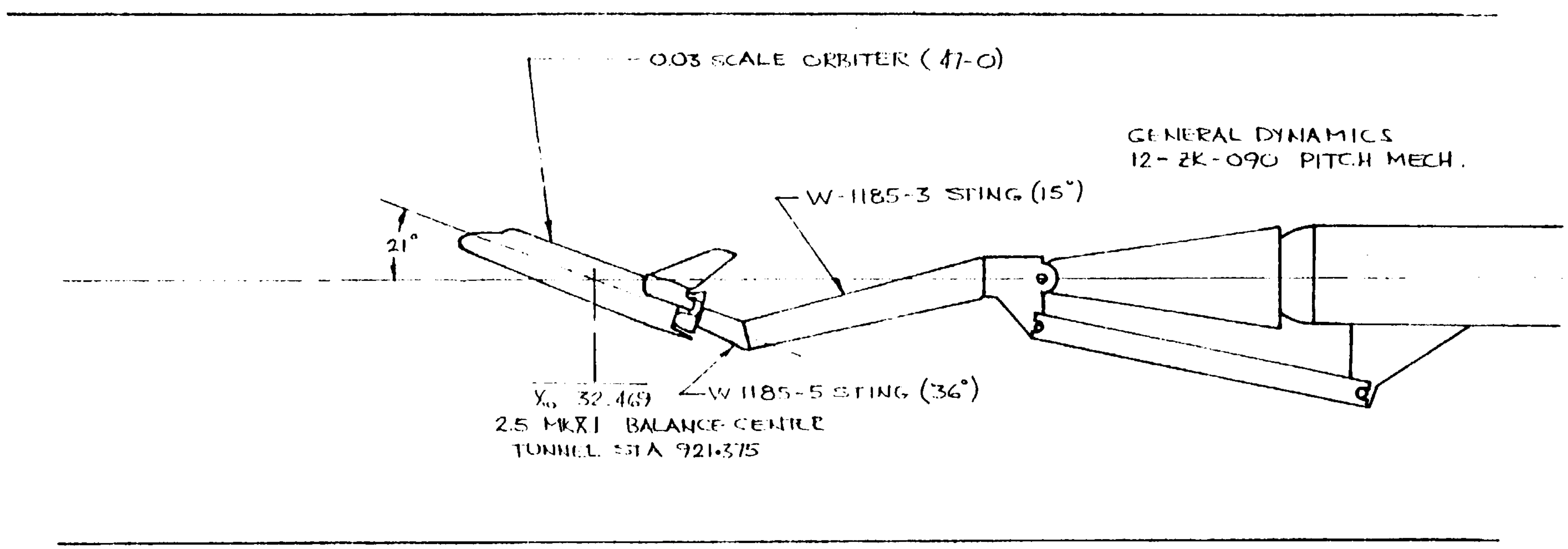


Positive Deflection of		Angle	Aero Forces and Moments	Hinge Moment
Rudder,	δr	$+\beta$, $-\psi$	$+C_Y$, $-C_n$	$-C_{h_r}$
Elevon,	δe	$-\alpha$, $-\theta$	$-C_m$	$-C_{h_e}$
Right,	δe_R	$-\phi$	$-C_\ell$	$-C_{h_{e_R}}$
Left,	δe_L	$+\phi$	$+C_\ell$	$-C_{h_{e_L}}$
Aileron,	δa	$+\phi$	$+C_\ell$	
Body Flap,	δ_{bf}	$-\alpha$, $-\theta$	$-C_m$	$-C_{h_{bf}}$

Figure 1b. Control Surface Deflections

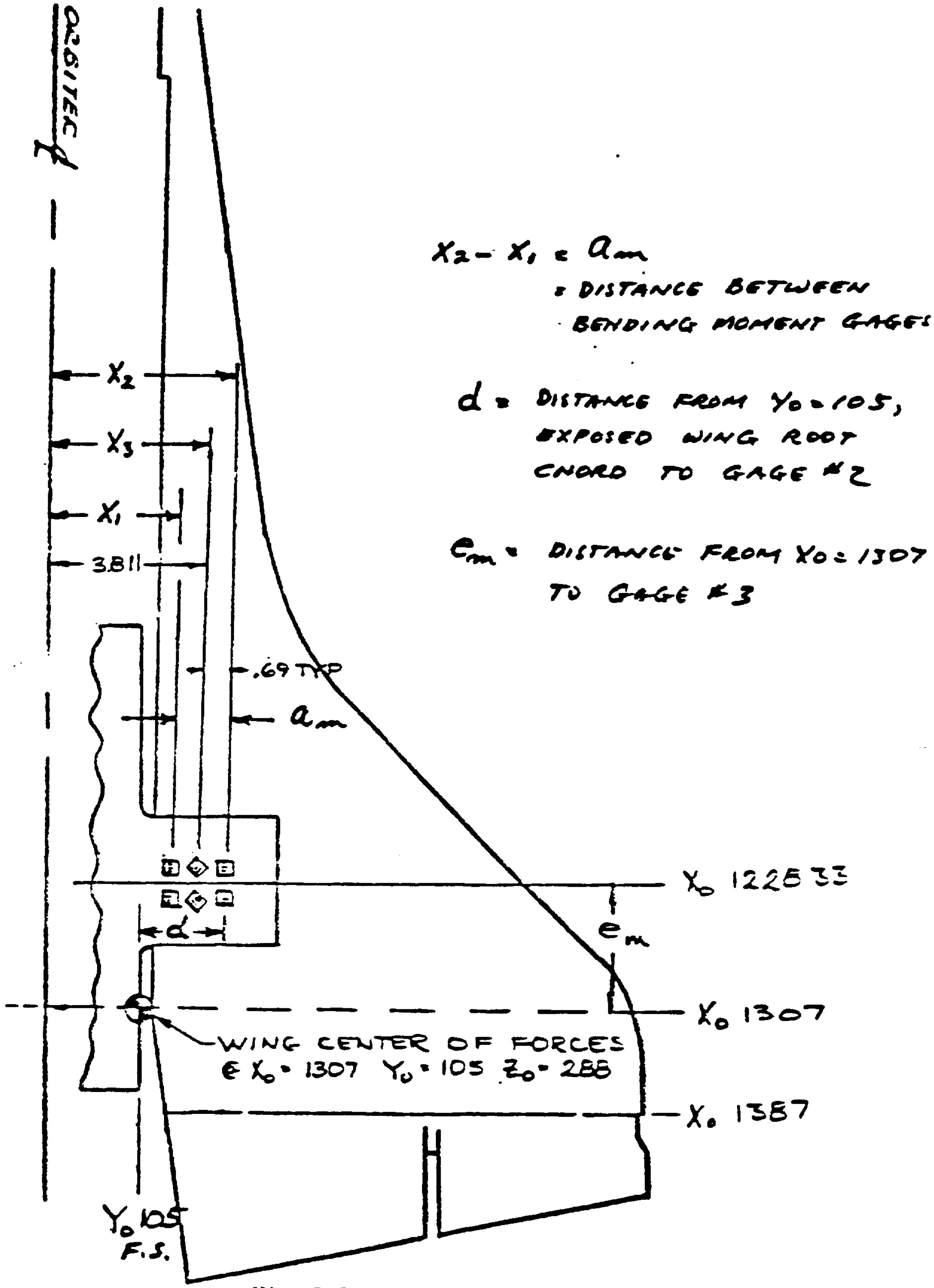


a. Orbiter Configuration
Figure 2. ›del sketches.



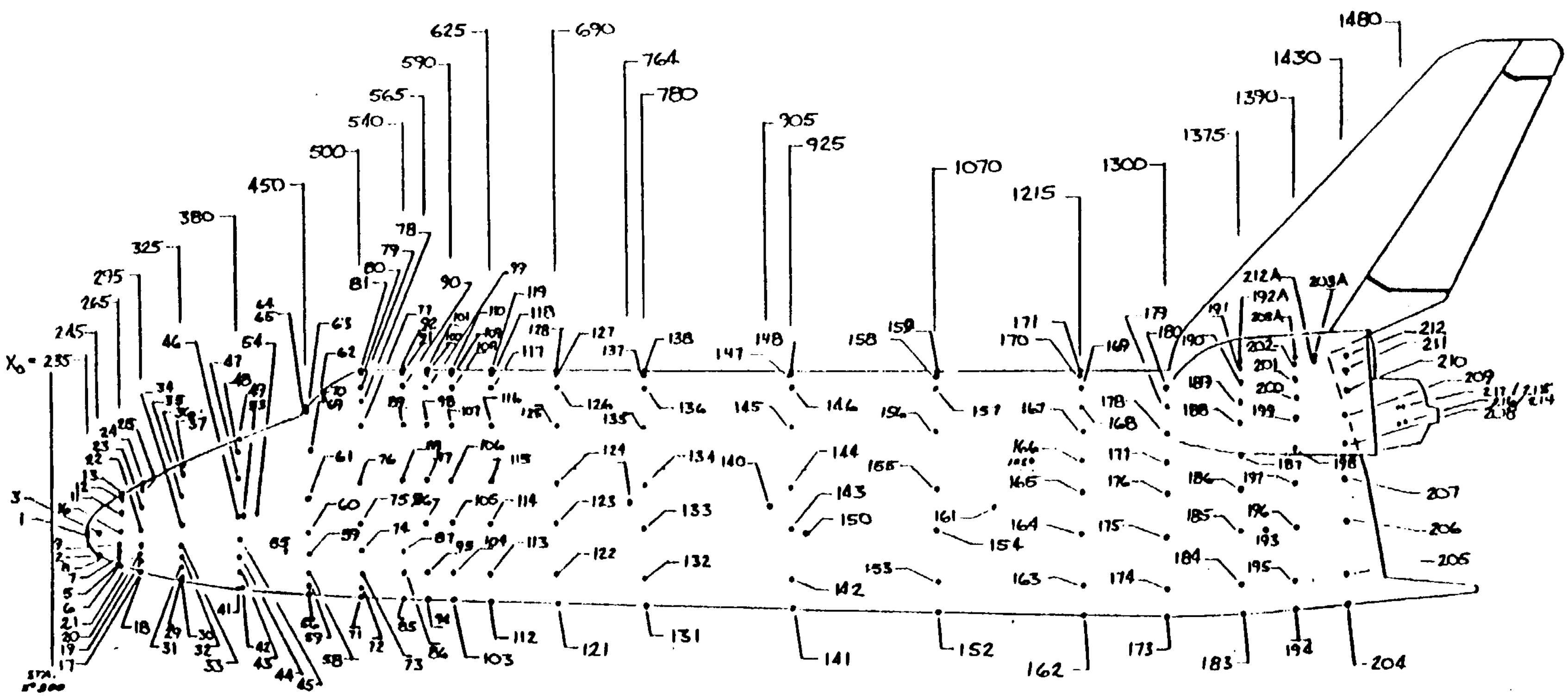
b. Model Installation - 8x7-Foot Wind Tunnel

Figure 2 (Continued)



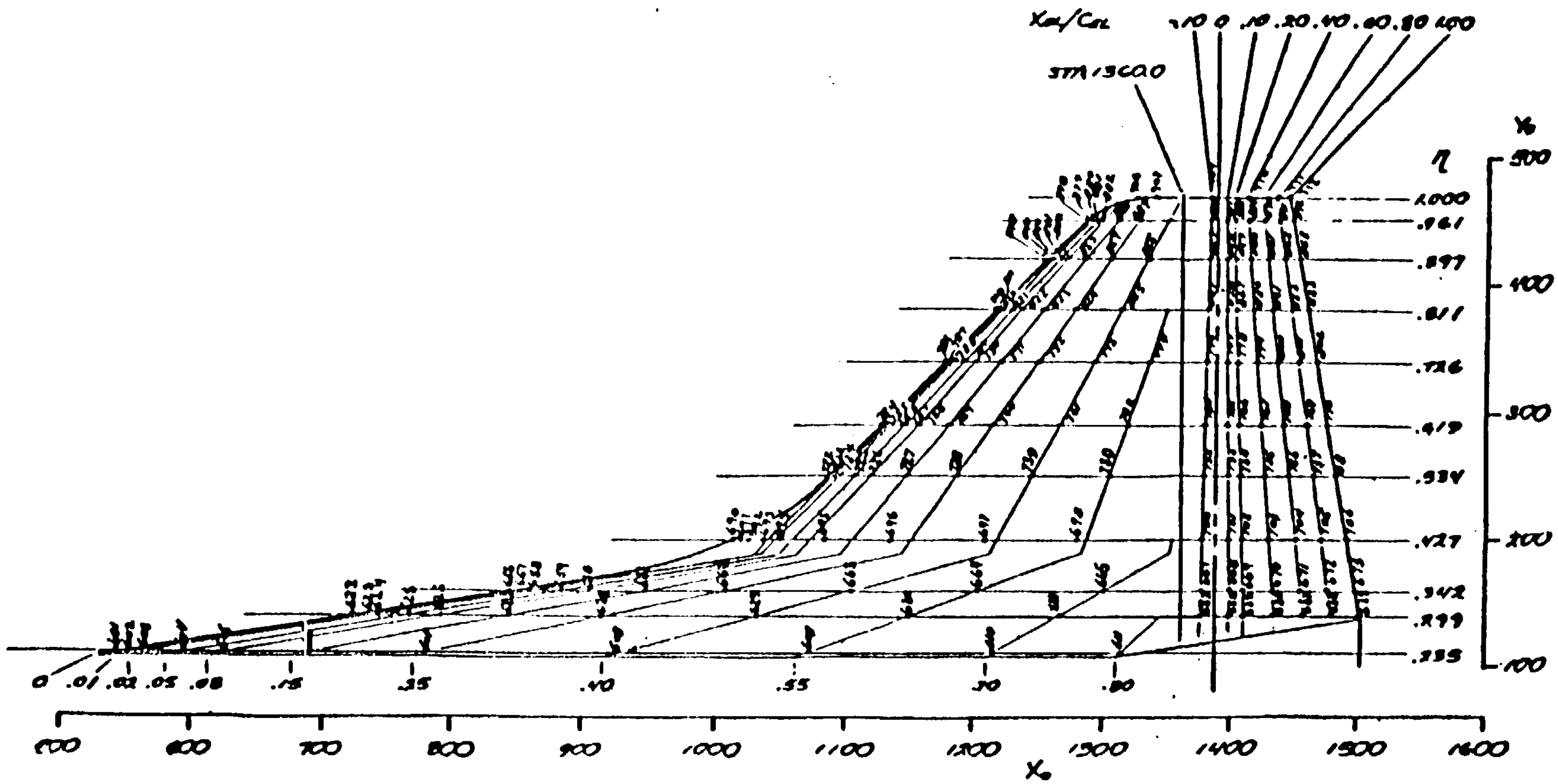
c. Wing Balance Transfer Diagram

Figure 2 (Continued)



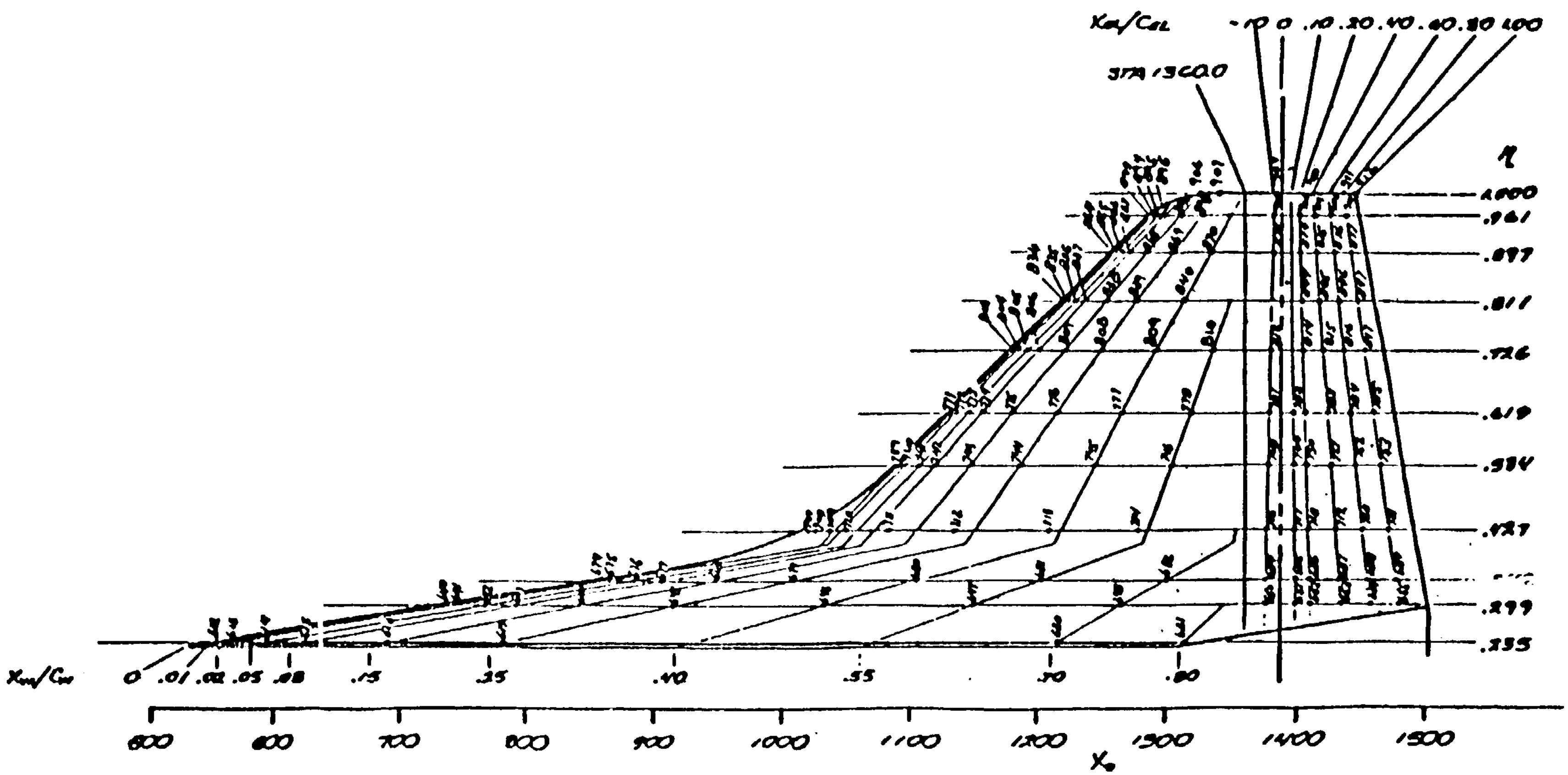
d. Orbiter Fuselage Pressure Instrumentation

Figure 2 (Continued)



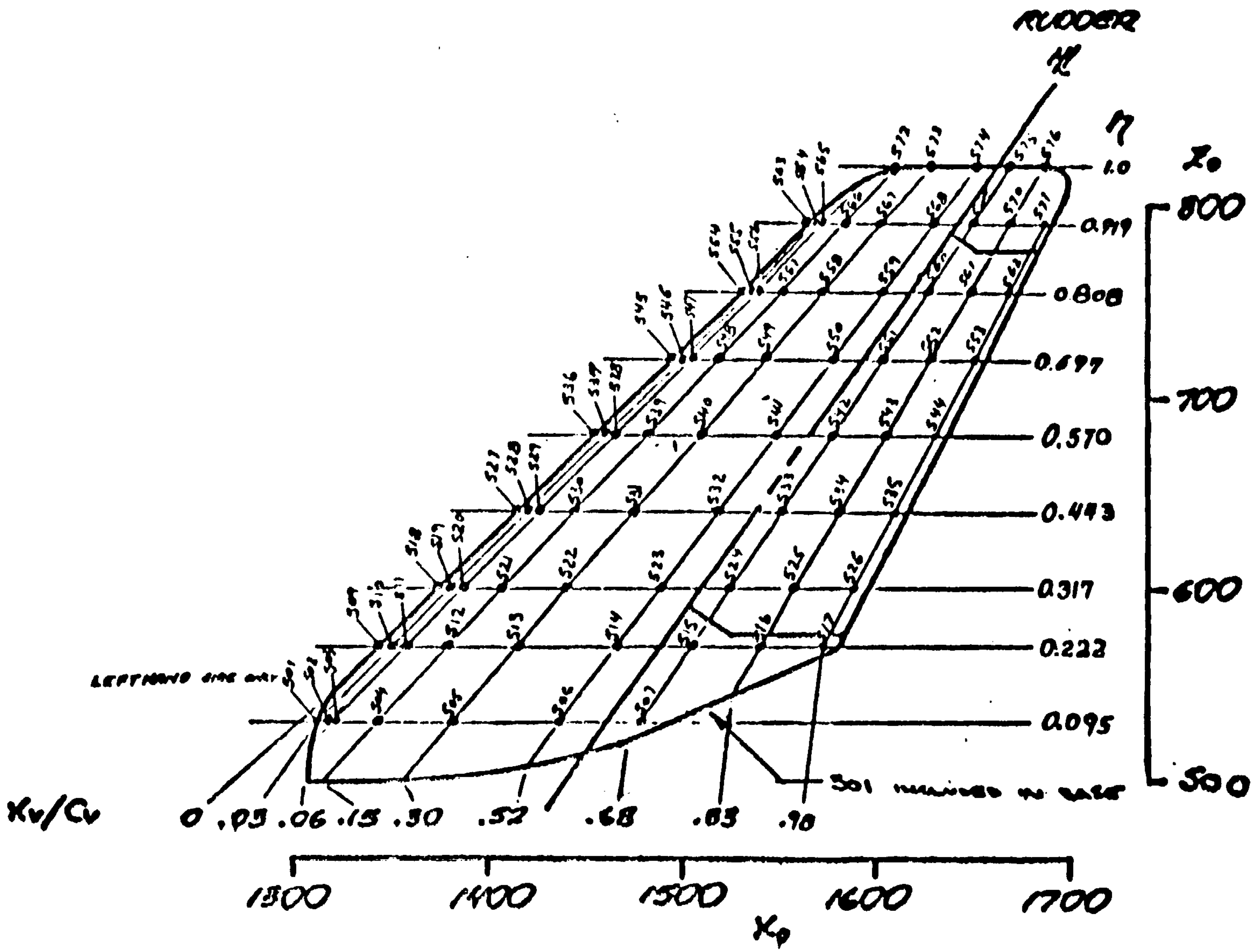
e. Orbiter Wing Pressure Instrumentation (Top Surface)

Figure 2 (Continued)



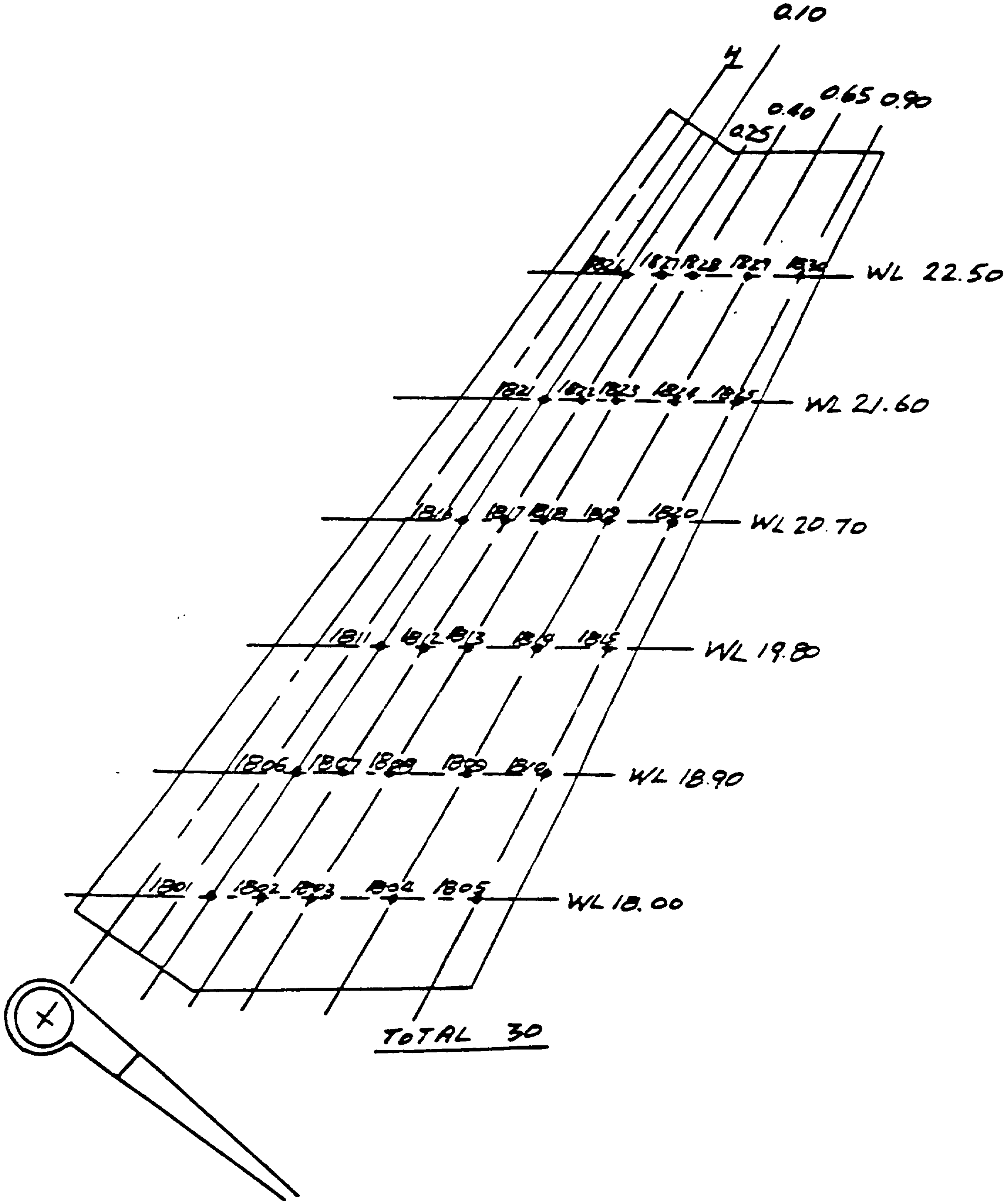
f. Orbiter Wing Pressure Instrumentation (Bottom Surface)

Figure 2 (Continued)



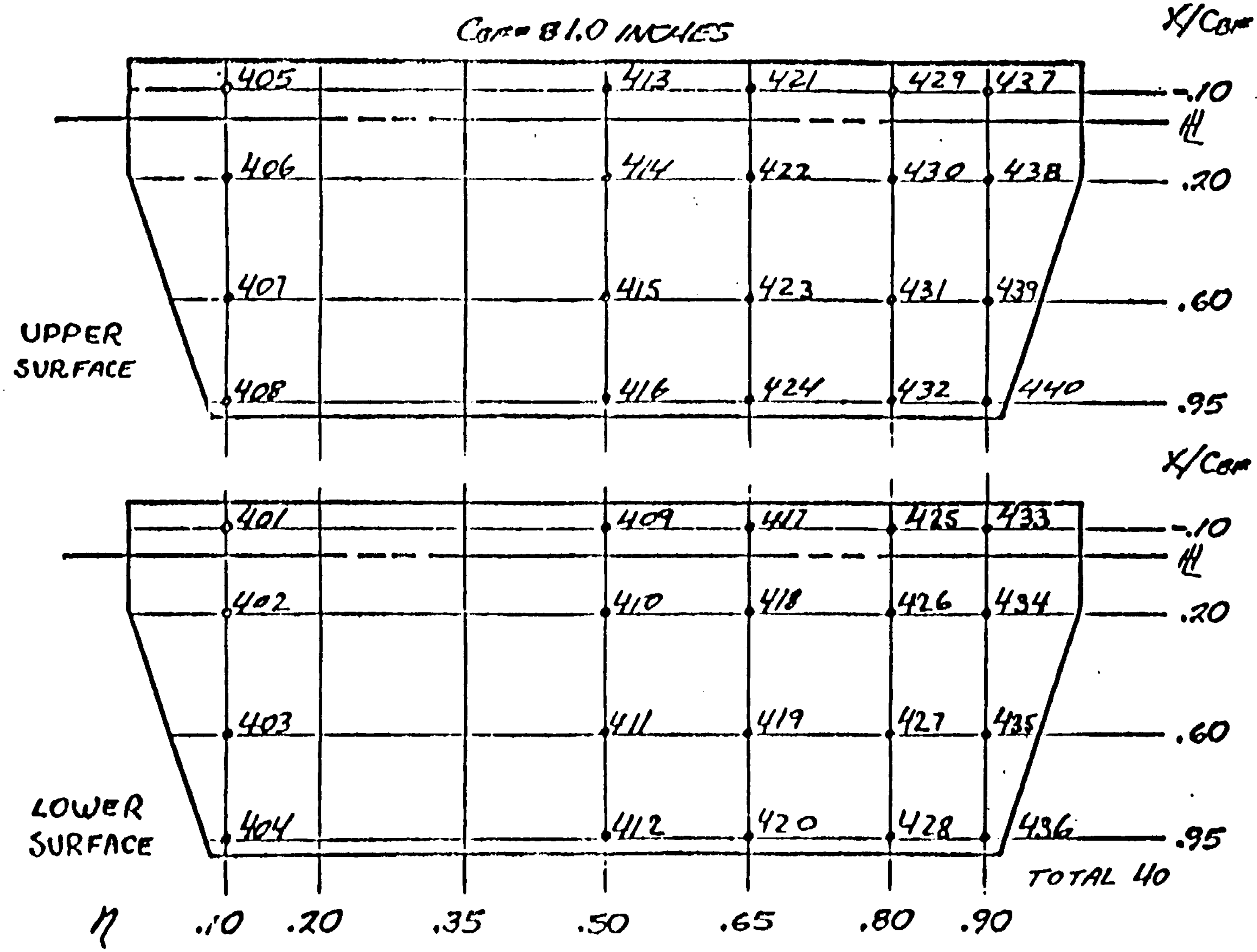
g. Orbiter Vertical Tail Pressure Instrumentation

Figure 2 ontinued)



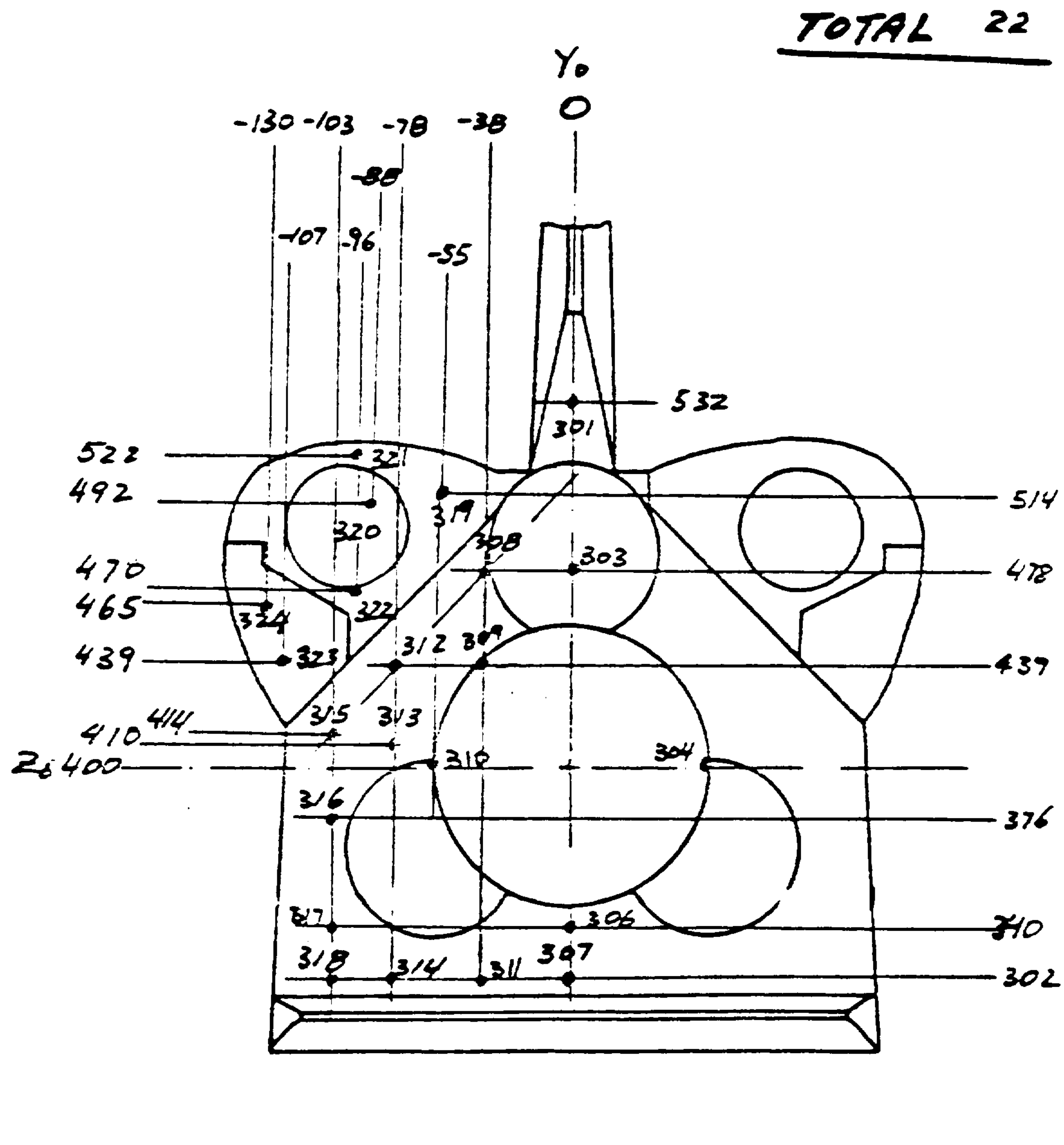
h. Inside Speedbrake Pressure Instrumentation

Figure 2 (Continued)



1. Orbiter Body Flap Pressure Instrumentation

Figure 2 [illegible]itinued)



j. Orbiter Base Pressure Instrumentation

Figure 2 (Concluded)

Appendix

Tabulated Data

(Microfiche Only)

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Pressure Data 4th Character ID	Description	Tabulated Page No.	Microfiche Page No.
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V	Vertical Tail (L.S.)	2822-2981	45-48

NOTE: Tabulated pressure data have been corrected for the bad orifice readings listed in Tables VIa through VIg.